Adaptive matched filters for contrast imaging

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1. Introduction

Conventionnal ultrasound contrast imaging systems use a fixed transmit frequency. However it is known that the insonified medium (microbubbles) is time-varying and therefore an adapted time-varying excitation is expected. We suggest an adaptive imaging technique which selects the optimal transmit frequency that maximizes the contrast tissue ratio (CTR). This ratio can be maximized if the microbubbles backscattered power is maximized.

$$CTR = \frac{E_{bubbles}}{E_{tissue}}, \text{ with } \begin{cases} E_{bubbles} & \text{the microbubbles backscattered power} \\ E_{tissue} & \text{the tissue backscattered power} \end{cases}$$

Two matched filters (MF) techniques are used to improve the image contrast. The first technique is an adaptive MF technique and the second is a RLS technique derived from identification theory.

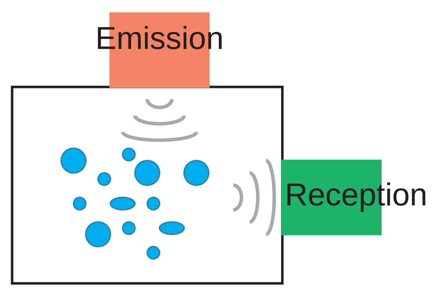
2. Materials

Microbubbles

- Microbulles SonoVue^{TM}: mean diameter of 4.5 μm with shell thickness of 1 nm ; Resonance frequency : $f_R = 2.1$ MHz
- Concentration: 1/2000 diluted solution of Sonovue^{TM}
- Immersed in a blood mimicking fluid (BMF)

Acoustical Measurements

- Arbitrary function generator piloted by Matlab®
- 2 perpendicular transducers :
  1. Emission : 2.25 MHz - BW 74%
  2. Reception : 3.5 MHz - BW 63%

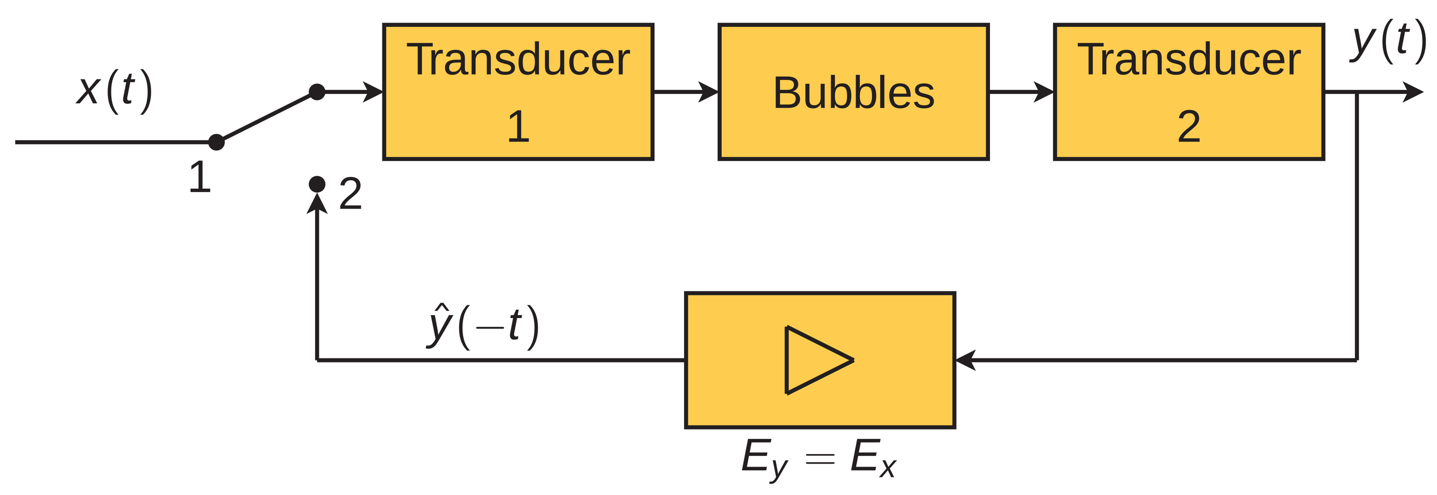


3. Methods

1. Switch in position 1
1.1 Sending a pulse on the bubbles
1.2 Receiving the backscattered signal
1.3 Repeating (1.**??**) and (1.**??**) 20 times
1.4 Linear combination(ACP) from this 20 signals
1.5 Identification system with an adaptive filter
2. Switch in position 2
2.1 Amplification of the signal such as $E_5 = E_2$ and reversal
2.2 Pulse is the signal
2.3 return to **??**

4. Matched Filter

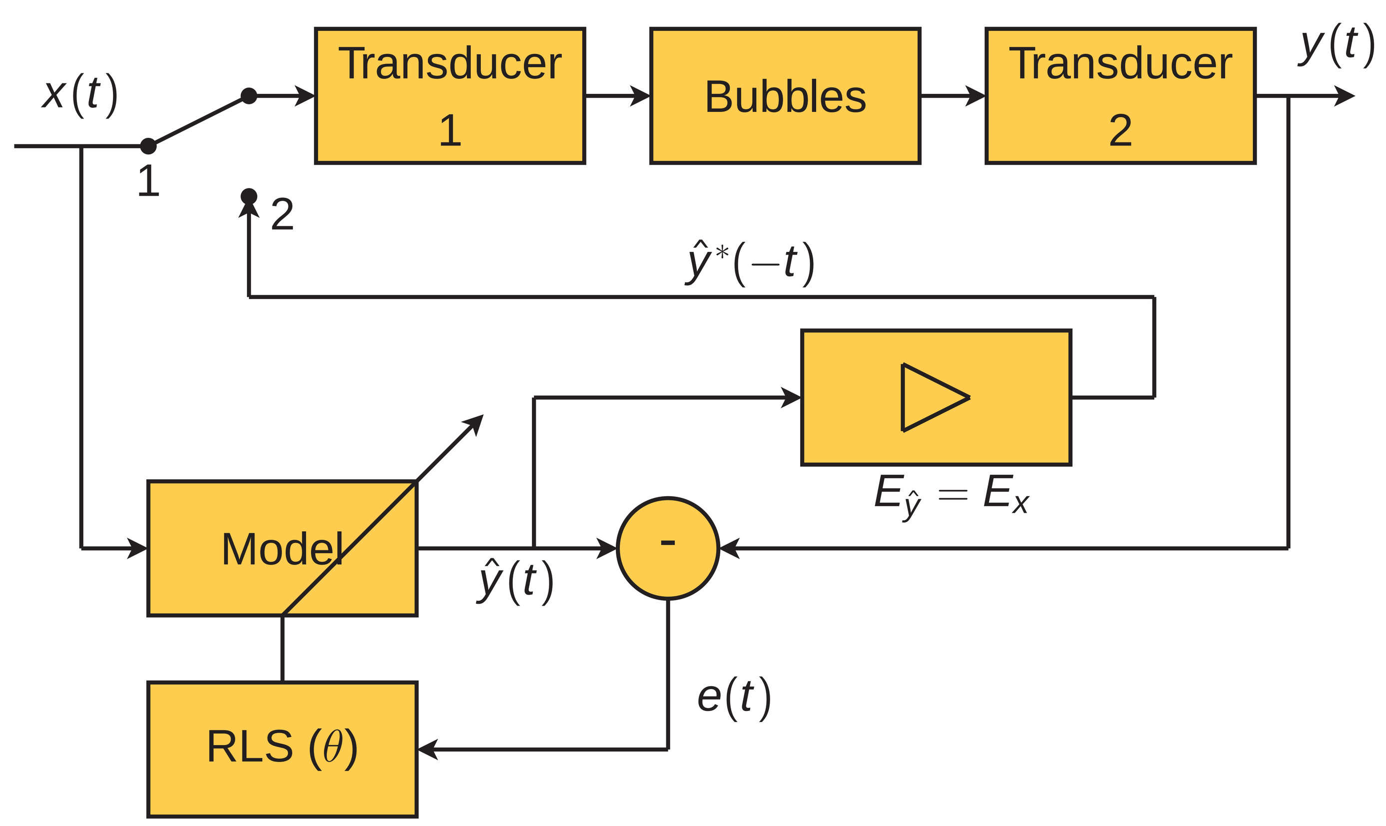
First Matched Filter



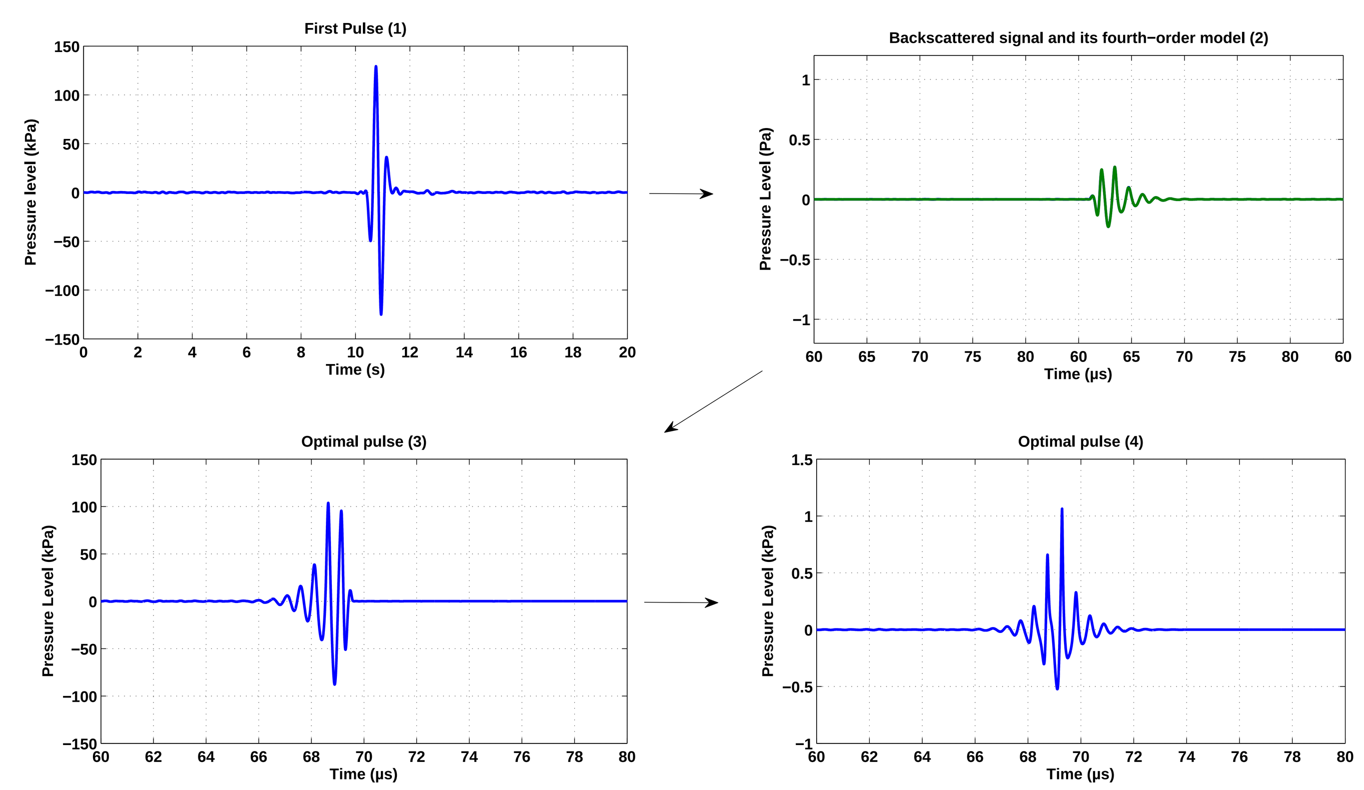
Recursive Least Squares (RLS) filter

Identification by RLS, *i.e.* minimizing the squared error such as

$$e_n = y_n - x_n^T \theta_{n-1}$$

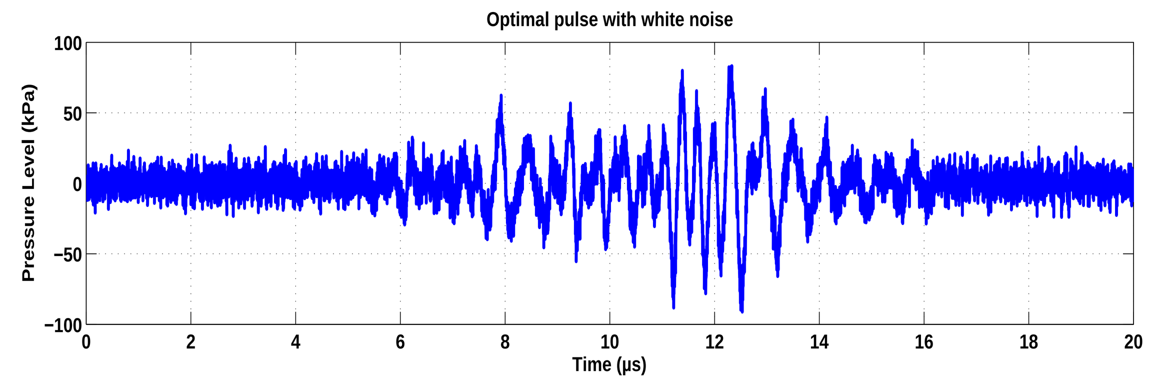


5.1 Results & Discussion : first simulation

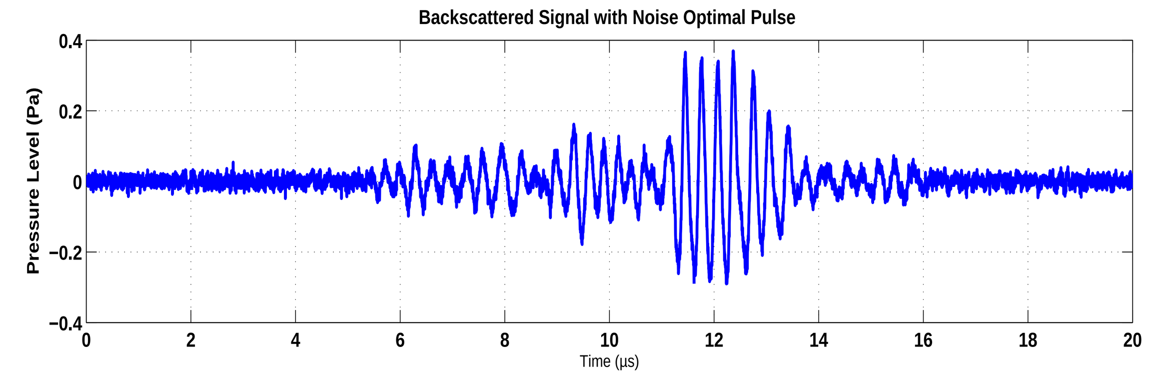


Gain between signal in (fig 1) and signal in (fig 4) : 17.68 dB

5.2 Results & Discussion : second simulation



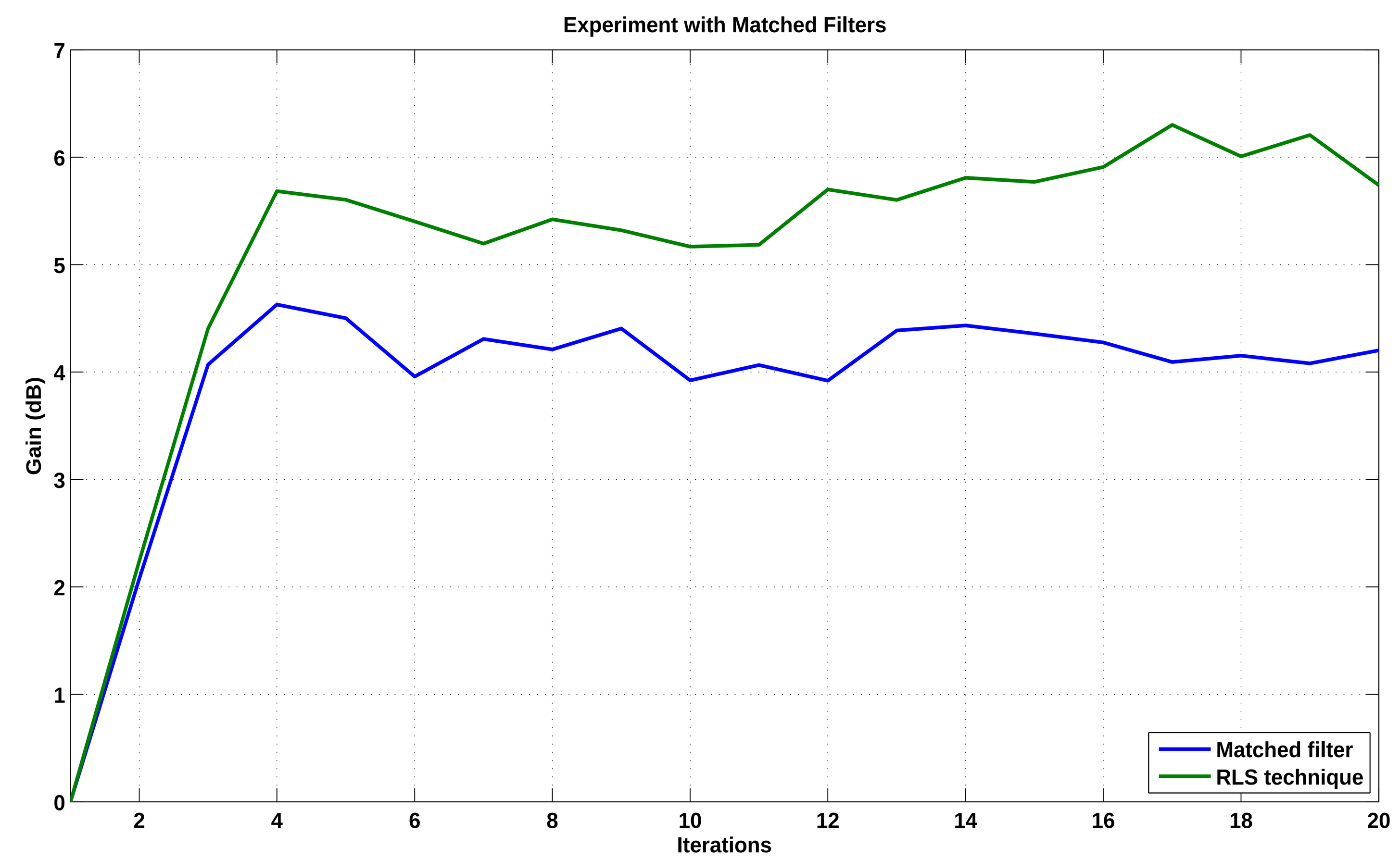
SNR = 4.74 dB



Gain with RLS : 24.72 dB
Gain without RLS : 10.85 dB

A Filter RLS of fourth order is sufficient to modelize the bubble system. The RLS filter allows us to extract the information of the bubble system better than the simple match filter.

5.3 Results & Discussion : experiment



Compared to the non-optimized imaging technique, the both proposed methods give a gain superior to around 5 dB.

- Advantage: gain improvement ;
- Drawback: increasing of the system complexity.

6. Conclusion & future prospects

- Optimization works well even though for nonlinear system ;
- Implementation in an open echograph.

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